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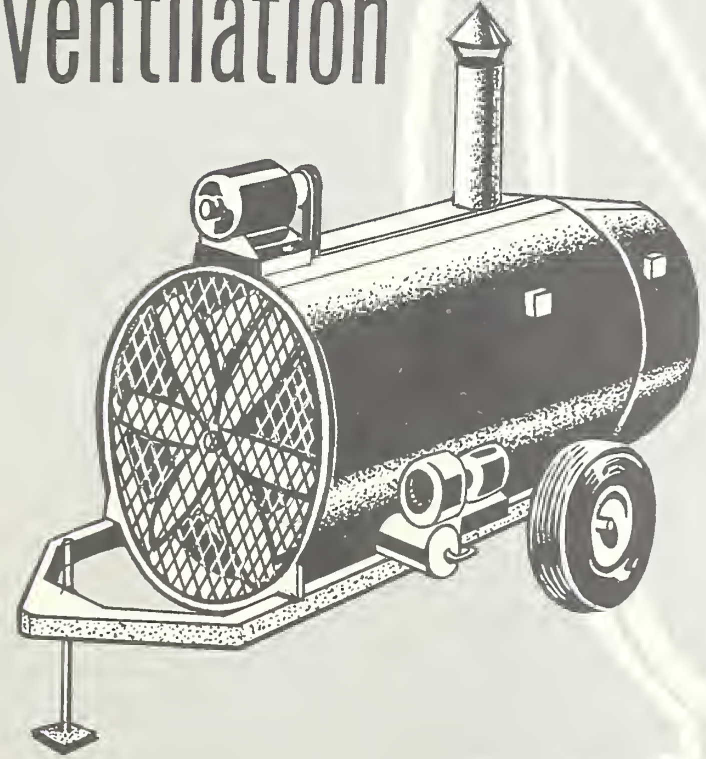
DRYING EAR CORN by mechanical ventilation



MISCELLANEOUS PUBLICATION No. 919
U. S. DEPARTMENT OF AGRICULTURE

DRYING EAR CORN by MECHANICAL VENTILATION

Prepared by Agricultural Engineering Research Division,
Agricultural Research Service

Many of the hazards of harvesting and storing corn can be removed by adopting mechanical ventilation for drying ear corn in storage on the farm.

With mechanical ventilation you obtain *controlled* drying, which overcomes the problem of storing wet corn harvested with mechanical harvesters.

This modern method of drying is valuable not only as a means of handling a high-moisture crop on an emergency basis, but also as a part of regular crop management. It fits in well with modern production, harvesting, and handling methods.

If you have controlled-drying equipment, you can store corn safely, market it without a moisture discount, and save it in wet years. You can harvest early, and thereby take advantage of good harvesting weather, reduce field losses from insects, obtain cleaner husking, lower harvesting costs, and complete harvesting in time for fall plowing and seeding of wheat or cover crops.

Power for a drier may be provided by an electric motor or by a gasoline engine. Drying may be accomplished with heated air or with unheated air. With heated-air drying, you can dry corn in any kind of weather, and the short drying time permits repeated use of the equipment. Advantages of unheated-air drying are: Little supervision required; lower initial equipment cost; no possibility of damage to grain from high-temperature air; no fire hazard.

General Requirements

Unheated Air

Ear corn with a moisture content of up to 30 percent in the kernels can be dried successfully by mechanical ventilation with unheated air in the Corn Belt or in other areas with similar climate.

If weather conditions are normal after harvest, the moisture content of the corn will drop from 30 percent to below 20 percent in 3 to 6 weeks of continuous blower operation. However, if the weather is especially humid after harvest, the corn may not dry down to 20-percent moisture before cold weather arrives. Under the latter condition, operate the fan until the corn is frozen. Complete drying with additional fan operation as the weather warms up in the spring.

Heated Air

Ear corn can be dried for storage or market by mechanical ventilation with heated air in any kind of weather and from any moisture content, although it is not usually economical to start with more than about 30-percent moisture in the kernels. Fuel costs will be about in proportion to the amount of water to be removed from the corn and will vary with the weather.

Follow this procedure:

1. Start harvest when the kernel moisture is between 25 and 30 percent. This will enable you to take advantage of good drying weather as well as good harvesting weather.
2. Make sure that corn to be dried is reasonably free of husks, silks, and shelled corn. Foreign material that cannot be removed should be distributed uniformly through the batch.
3. Provide an adequate quantity of drying air in an even flow through the crib. See table 1 for recommended rates of airflow.
4. Arrange air ducts, or tunnels, to distribute air uniformly. The air should travel about the same distance through the corn in all parts of the crib.
5. As a general rule, heated-air drying temperatures should not be more than 130° to 140° F. For corn to be used for feeding, air temperatures up to 180° F. may be used in noncombustible buildings. For seed corn, the drying-air temperature should not exceed 110°.

Table 1.—*Recommended minimum rates of airflow and maximum number of bushels of ear corn that should be dried per fan horsepower by mechanical ventilation*

Kernel moisture content (percent)	Recommended minimum airflow rate per bushel	Maximum quantity of ear corn that can be dried per fan horsepower [1]
	C.f.m.	*Bushels*
30	5	800
25	3	1, 300

[1] Calculated on basis of a static pressure of ¾-inch water gage and a fan air delivery rate of 4,000 cubic feet per minute per horsepower.

How Ear Corn Dries

As air is forced through the corn, drying first occurs where the air enters. The air may become saturated in going through the first foot or two of corn and no drying will occur above that, until the first layers have dried. As the bottom layer dries, the air moves farther up before being saturated and the corn in the next layer begins to dry. A drying front moves through the corn in the direction of airflow, and finally the corn at the top of the bin becomes dry. The drying front moves faster where the air moves faster. It is important to have the drying front reach the top layer at about the same time at all points. Otherwise the operation wastes power. This is the reason for attempting to get uniform airflow through all the corn.

Since the corn in the upper layers dries very little until the whole drying operation is nearly completed, it is subject to fast deterioration and mold activity. It is necessary to move the drying front through all the corn before deterioration in the upper layers has gone too far. This is done by supplying an adequate volume of air for the conditions. Table 1 shows air volumes that usually are sufficient to prevent excessive spoilage in the upper layers.

Use of Artificial Heat

In most seasons in the Corn Belt the suggested rates of airflow will dry the corn satisfactorily without adding any heat. In areas where the temperature or humidity is high after corn harvest, greater volumes of air are needed. Adding heat to the drying air will shorten the drying period and result in a lower final moisture content. Supplemental heat—enough to raise the temperature by 10° to 20° F.—may be used to assure continuous drying regardless of how high the relative humidity may be.

High-temperature drying, using temperature rises of more than about 20°, may be used to substantially shorten the drying period. Air temperatures up to about 180° are used. Ordinarily high-temperature drying is not used unless there is a good reason for completing the drying quickly. Quick drying would be justified if you wished to fill the crib twice in one season. The first filling may be dried with high-temperature air in a few days and shelled out, emptying the crib for a second filling. The second filling would be dried with the same equipment, except that the heater might not be used. The drying time would be much longer for the second filling.

Quick drying would also be justified if you wished to dry several cribs with the same equipment.

Temperature Limits

In using high-temperature air, the following upper limits of temperature should be observed:

	°F.
For seed corn	110
For corn for the milling industry	130 to 140
For feed	180 to 200
In a bin constructed of combustible materials	165

Safety

In any fuel-burning equipment there is an element of fire hazard. Inform your insurance company before you install heated-air equipment. Familiarize yourself with the manufacturer's instructions and follow them.

Equipment

Unheated Air

The equipment required for drying with unheated air is a drying structure, a suitable fan, and a power unit, preferably an electric motor. The greatest number of bushels of corn that should be dried per fan horsepower are shown in table 1. If larger quantities of corn are dried per horsepower, there will be more risk of unsatisfactory drying. If smaller quantities of corn are dried, the cost per bushel will be increased.

As shown in table 1, the fan should deliver 4,000 cubic feet per minute of air per horsepower against a static pressure of ¾-inch water gage. Since it is not practical to test fan performance on a farm job, you will have to rely on the manufacturer's rating of the fan. You would be unwise to buy any fan lacking a reliable rating, or one that has no pressure listings with the cubic-feet-

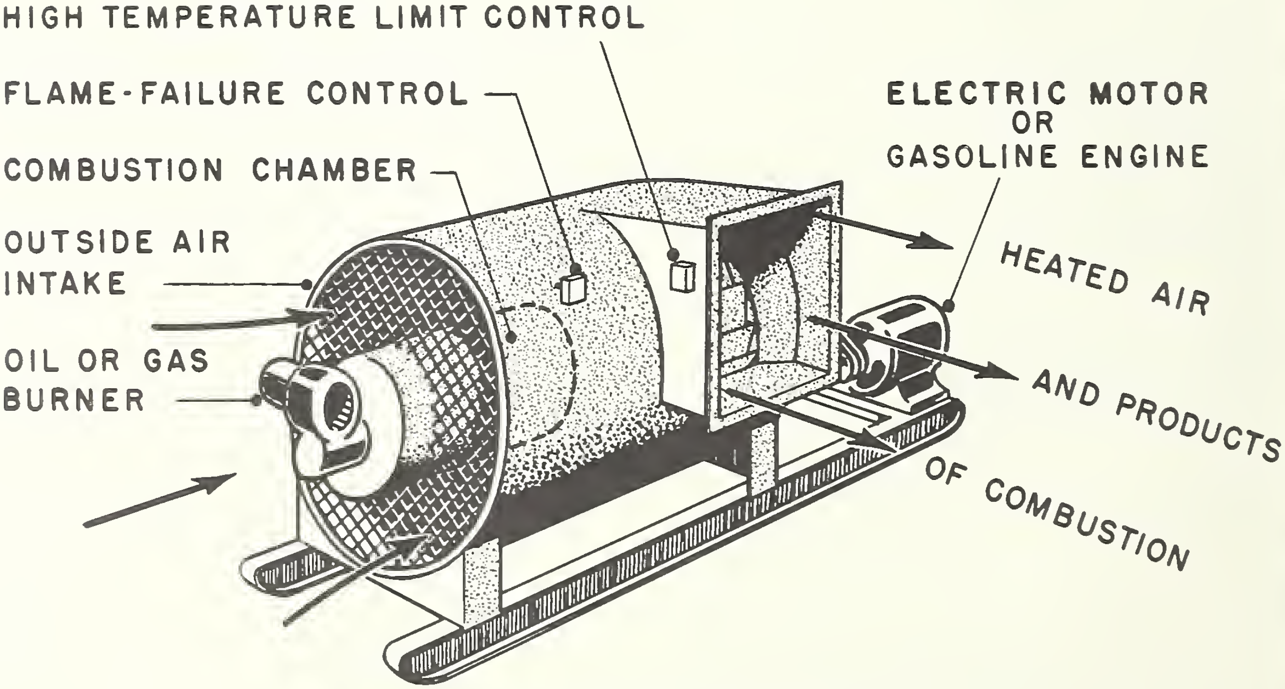

HIGH TEMPERATURE LIMIT CONTROL
FLAME-FAILURE CONTROL
COMBUSTION CHAMBER
OUTSIDE AIR INTAKE
OIL OR GAS BURNER
ELECTRIC MOTOR OR GASOLINE ENGINE
HEATED AIR AND PRODUCTS OF COMBUSTION

Figure 1.—Portable direct-heat air heater.

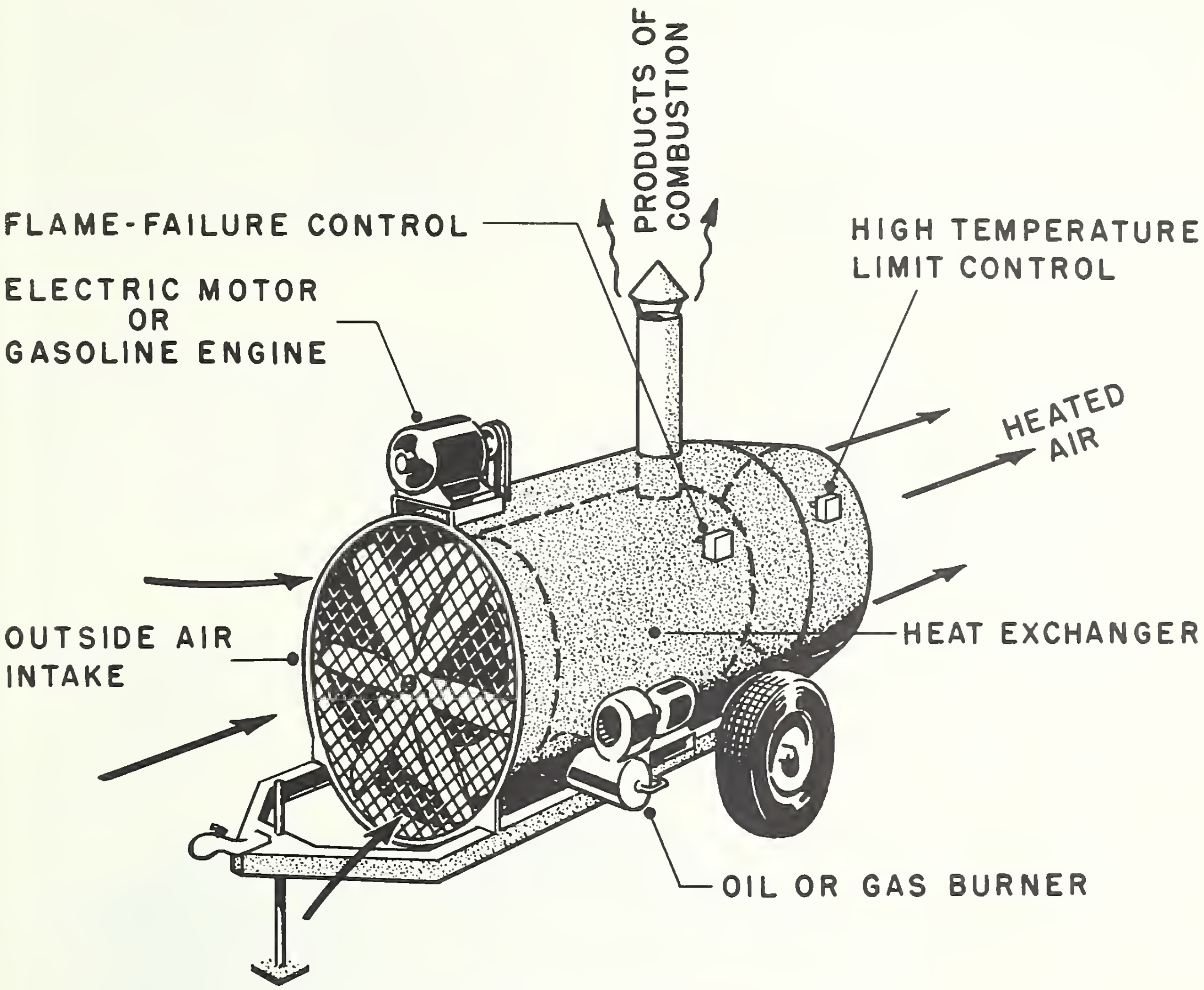


Figure 2.—**Portable indirect-heat air heater.**

per-minute ratings. Wind stackers, ensilage or hay blowers, or home or barn ventilating fans are not suitable for corn drying.

Where electric power is not available, gasoline-engine power can be used to drive the fan. The main objection to a gasoline engine for this purpose is that it requires more attention while in operation than an electric motor, and more maintenance.

Since ventilation usually continues for several weeks, one fan unit will dry only one crib of corn each year.

Heated Air

Equipment needed for heated-air drying includes a heater, a power-driven fan, and a crib or drying bin for the corn. Use the same fan capacity as for drying with unheated air (table 1).

The heater may burn oil, natural gas, or liquified petroleum gas. Such equipment has two characteristics that determine its performance in drying grain: (1) The rate at which heat is supplied (rate of fuel consumption per hour) and (2) the rate of air supply in cubic feet per minute.

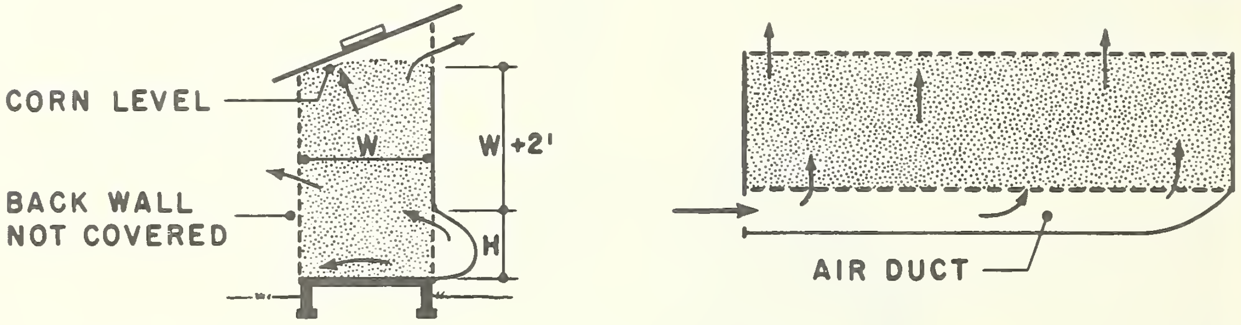
Heaters are classed as "direct heat" or "indirect heat." The types are illustrated in figures 1 and 2. At least two automatic safety controls are needed with either kind. These controls are: (1) A device to shut off the fuel supply if the flame fails and (2) one to shut off the fuel supply if the temperature goes too high.

Figure 1 shows a direct-heat unit in which the products of combustion are mixed with the drying air.

In the portable indirect-heat unit shown in figure 2, the burnt gases are discharged through a smokestack. Air, heated as it comes into contact with the heat-exchanger, is blown through the grain. Some heat is lost through the smokestack. The fire hazard is less than with a direct-heat unit.

Selecting a Fan

When selecting a fan, the most important factors to consider are suitable design, size, and speed. Of secondary importance is whether the fan is a propeller or centrifugal type. Most fan manufacturers provide performance ratings in the form of tables or charts for their fans. The ratings



DUCT HEIGHT (H) SHOULD BE AT LEAST 1/3 OF CRIB WIDTH (W)

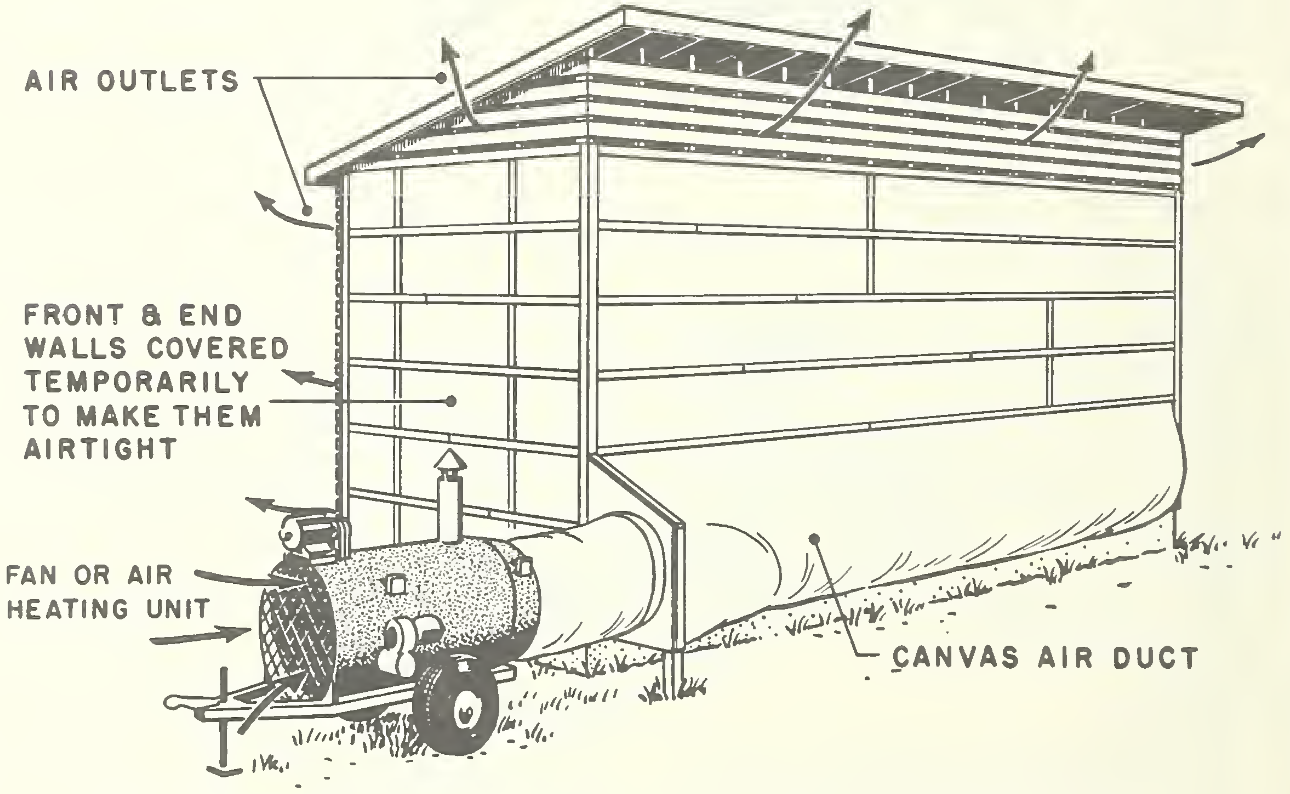

AIR OUTLETS
FRONT & END WALLS COVERED TEMPORARILY TO MAKE THEM AIRTIGHT
FAN OR AIR HEATING UNIT
CANVAS AIR DUCT

Figure 3.—Single crib partly enclosed with canvas or reinforced paper. Air duct of canvas, outside the crib.

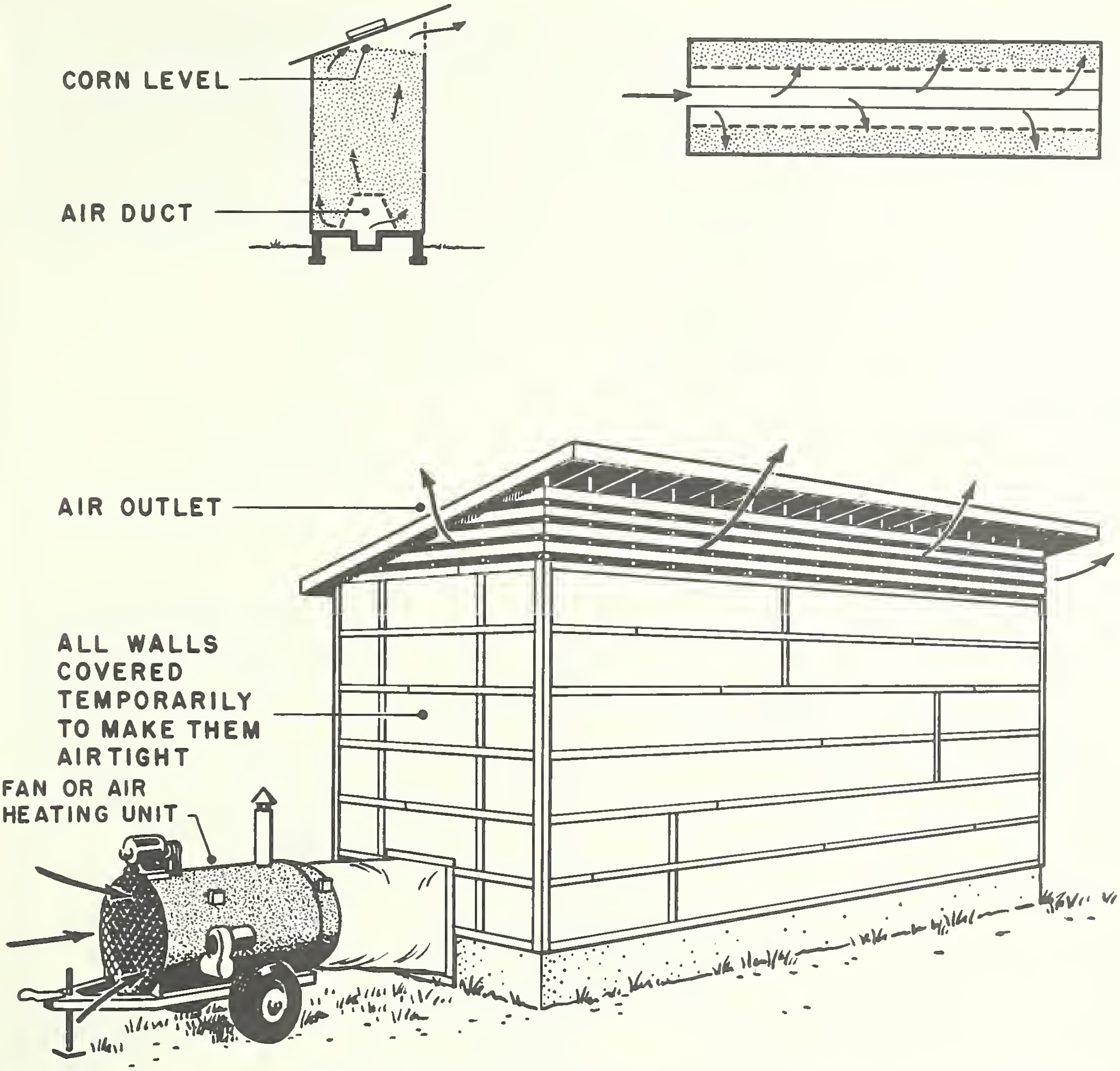


Figure 4.—Air duct on inside of single crib. The crib is enclosed with canvas or reinforced paper.

show the relation between speed, horsepower, static pressure, and air volume. A fan installed without reference to its performance characteristics cannot be expected to operate adequately or economically.

Fan performance ratings are based on tests in a laboratory where the fan is operated with carefully adjusted inlet and outlet ducts for the air. In most drying installations there are inlet and outlet losses of pressure. These pressure losses are in addition to the losses due to duct friction, resistance of the grain, etc., and should be included when estimates of fan capacity are made from performance ratings. The static pressure drop through the corn itself when drying ear corn usually will be from ½ to ¾ inch, water gage.

Cribs, Bins, and Air Ducts

Various types of cribs, bins, and air-duct arrangements for use in drying and storing ear corn are illustrated in figures 3 through 15. Ducts and ventilators should have a cross section area of 1 square foot for each 1,000 c.f.m. of air delivered to the corn. The main duct throughout should be larger, therefore, than the fan outlet, and it should be free of sharp turns.

You can use canvas or reinforced paper, fastened with wooden strips about 2 feet apart and at right angles to the airflow, to partly enclose a crib of the type shown in figure 3, 4, or 5. Also place strips over laps or joints. Canvas, as shown in figure 3, or reinforced paper over a light wooden frame makes a suitable air duct outside and along the front of the crib. You can attach the canvas or paper to the crib after it has been filled. Air blown into the duct moves across and upward through the corn and out the back and the upper part of the crib. After mechanical ventilation is complete, you can easily remove the wall covering and duct to permit normal ventilation of the corn.

A slatted or wire air duct has been installed on the inside of the crib shown in figure 4. You can use canvas or reinforced paper to enclose the

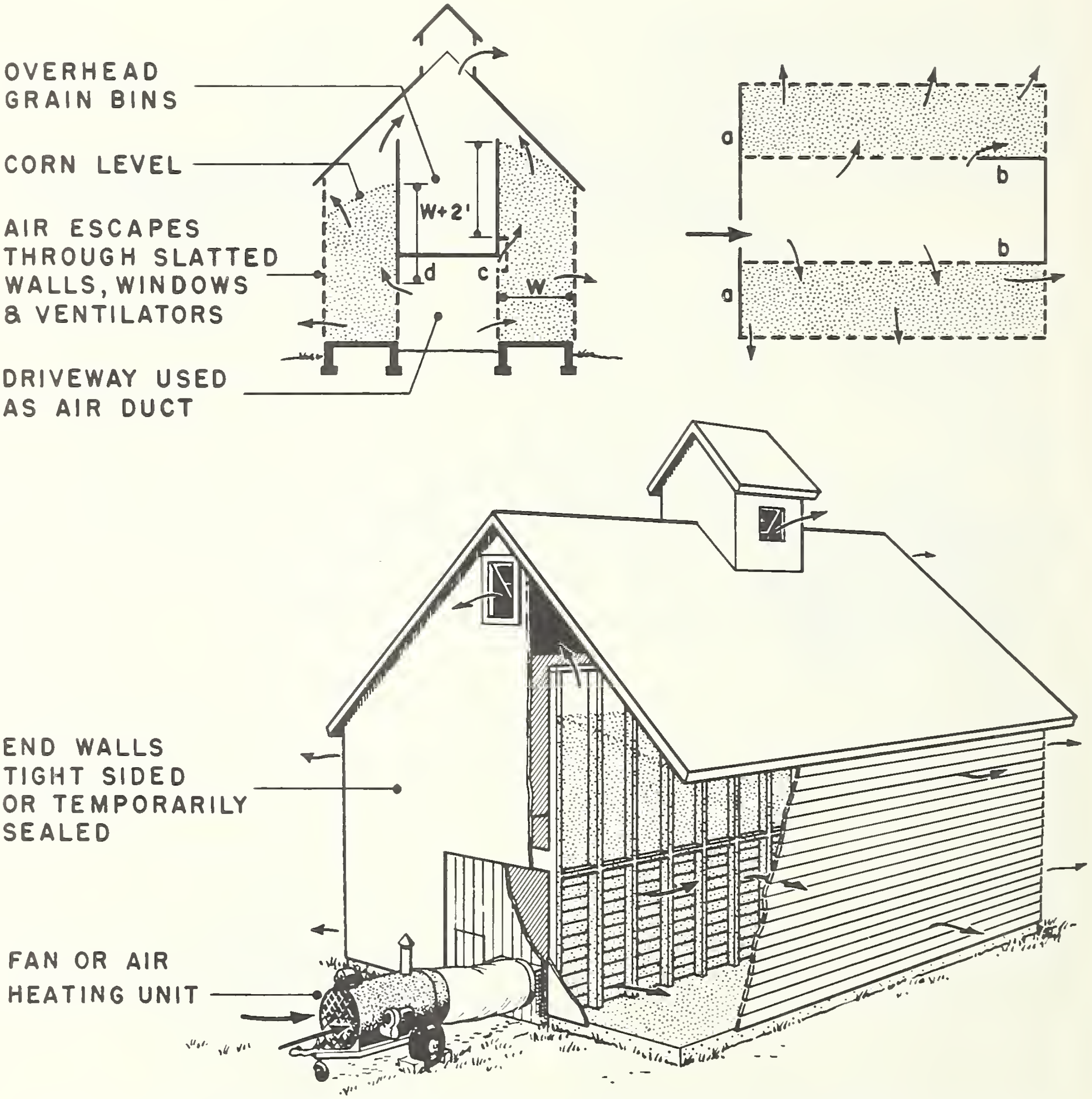

OVERHEAD GRAIN BINS
CORN LEVEL
AIR ESCAPES THROUGH SLATTED WALLS, WINDOWS & VENTILATORS
DRIVEWAY USED AS AIR DUCT
W+2'
d
c
W
a
b
b
a
END WALLS TIGHT SIDED OR TEMPORARILY SEALED
FAN OR AIR HEATING UNIT

Figure 5.—Large rectangular double crib prepared for drying ear corn and equipped with drier to supply heated air.

crib in the same manner as for the crib in figure 3. The only difference is that the back of the crib in figure 4 has also been covered, so that air blown into the duct moves upward through the corn and then out the upper part of the structure. The diagram at top, left, of figure 4 shows the duct placed over a shelling trench. The trench must be airtight at the end opposite the fan.

You can prepare the large rectangular double crib shown in figure 5 for drying ear corn by closing the driveway doors and sealing them with reinforced paper. Or, you can place airtight bulkheads at each end of the driveway. If the end walls are not tight, cover them (shown as *a* in fig. 5), or cover the driveway walls (shown as *b*) back 6 to 8 feet from the crib ends. Covering the end walls is better.

Sometimes the studs outside an overhead bin are slatted to maintain an air space between the ear corn and the wall. This permits better circulation for natural ventilation. For mechanical drying, remove the slats or block the space to prevent short circuit of air. However, if the height of the overhead-bin wall in high cribs is greater than the crib width, leave some slats at the bottom of the bin-wall studs (shown as *c* in fig. 5).

If the crib is only partly filled, and the height of corn above the bin floor is not 2 or 3 feet greater than the width of the crib, the upper part of the driveway wall should be covered as shown at *d* in figure 5 to provide an even flow of air through the corn.

Narrow alleyways in cribs of the type shown in figure 6 are used as air ducts and for unloading. The end walls of this type of crib must be tight, but use slats in the side walls and in the walls of the alleyway. This will permit both natural and mechanical ventilation.

Use of a slatted, removable air duct down the center of the driveway of the double crib shown in figure 7 permits filling of ear corn into both cribs and the driveway area. Set the duct on the driveway floor. Air blown into the duct flows outward and upward through the corn.

Installation of a duct or tunnel system will enable you to dry and store ear corn in a prefabricated general-purpose building of the type shown in figure 8. General-purpose buildings are made of either metal or wood. Some have straight sides instead of arched ribs.

A slatted inside wall must be installed to allow air to pass through the corn to the sidewalls of the bin. A slatted sectional air duct runs down the center of the floor.

You can use either snow fencing or welded wire to build a temporary circular crib of the type

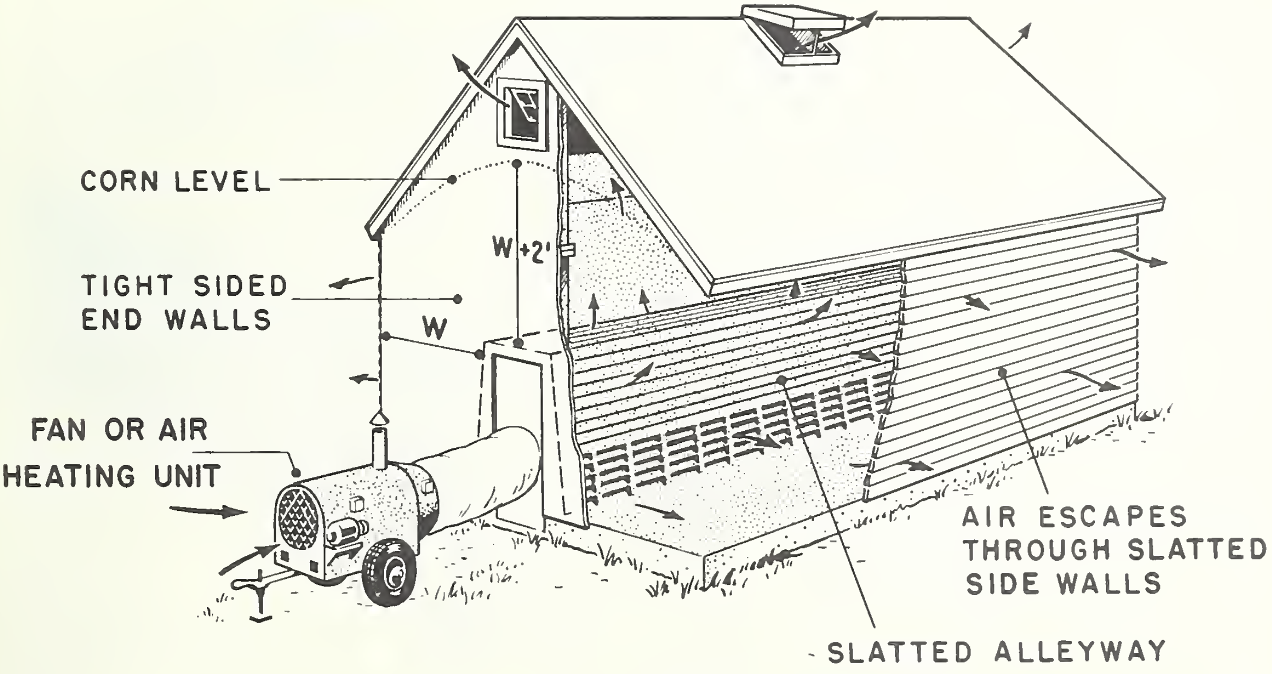


Figure 6.—Wide crib with 4-foot alleyway. The alleyway is used as an air duct and also for unloading the crib.

shown in figure 9. The air entrance and main ducts must be installed before the crib is filled.

The prefabricated high round crib in figure 10 has perforated walls and a vertical, slatted main air duct, which make it readily adaptable to mechanical drying. If you fill the crib only partially, block the main air duct for more efficient drying. Place the blocking below the surface of the corn at a distance equal to the distance from the duct to the wall plus 2 feet. Seal walls of the duct above the blocking to prevent a short circuit of the drying air. Use heavy pasteboard, plywood, reinforced paper, or any other material that makes the wall airtight. Or you can form the seal by filling the duct above the blocking with corn if you decide to leave the crib only partially filled.

Uniform air flow is difficult to get in an oval-type masonry crib such as shown in figure 11. If you have such a crib, you can use the arrangement illustrated for fairly uniform air distribution. The vertical air duct shown inside the crib will help to provide a uniform airflow to the sidewalls and will also improve air circulation through the corn in the upper part of the crib, near the walls of the overhead grain bin.

The false floor of the circular metal bin shown in figure 12 is of perforated metal. Cover the floor

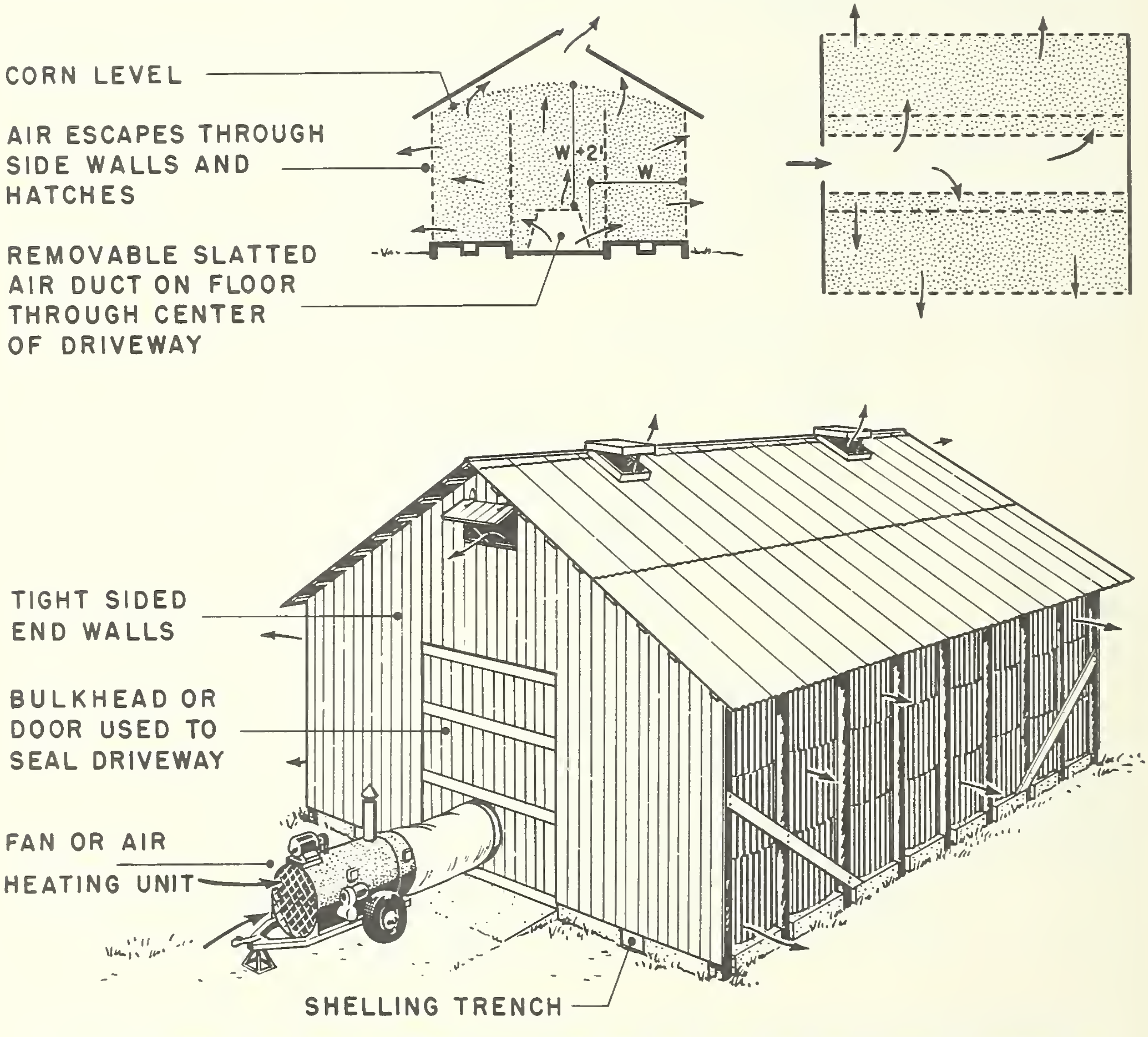

CORN LEVEL
AIR ESCAPES THROUGH SIDE WALLS AND HATCHES
REMOVABLE SLATTED AIR DUCT ON FLOOR THROUGH CENTER OF DRIVEWAY
W+2'
W
TIGHT SIDED END WALLS
BULKHEAD OR DOOR USED TO SEAL DRIVEWAY
FAN OR AIR HEATING UNIT
SHELLING TRENCH

Figure 7.—**Double crib without overhead bins, adapted for drying ear corn. Drier is attached for supplying heated air.**

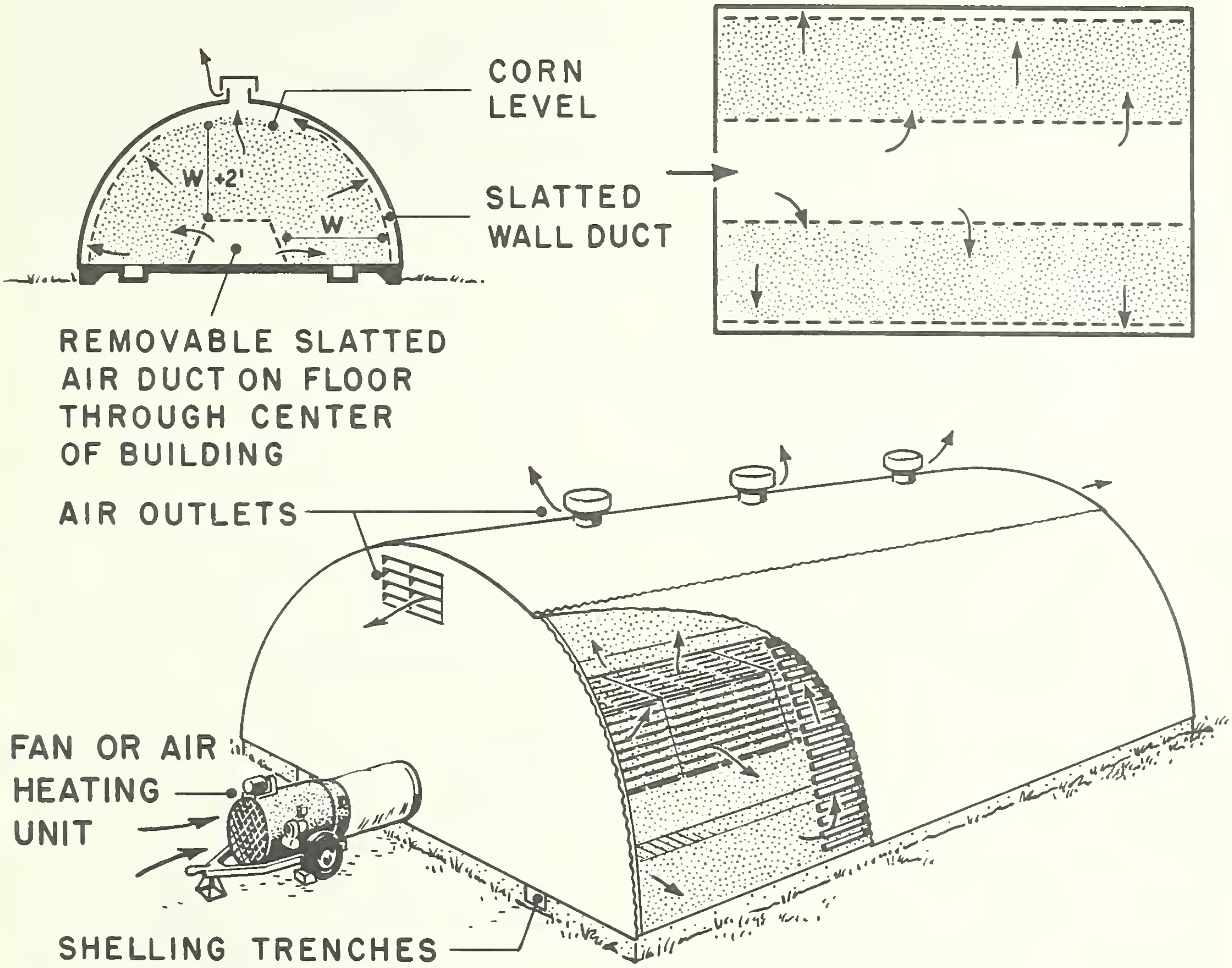


***Figure 8.*—General-purpose building equipped with air duct and drier for drying ear corn with heated air.**

evenly with ear corn at least 4 feet deep before starting the drier. Ear corn can be dried at depths up to 16 feet or even deeper. If a conveyor is to be used beneath the perforated floor, place this floor at least 16 inches above the ground or the permanent floor. Support the false floor on wood framing and concrete blocks or on other suitable supports. Place the blocks so that air can circulate through the openings. Provide one block for each 40 bushels (70 pounds per bushel) of ear corn or 50 bushels of grain that can be placed in the bin.

Perforations should be distributed uniformly and should amount to 7 to 10 percent of the total area of the floor. You will find it best to mount the perforated floor in removable sections so that the space under the false floor can be cleaned easily. Several companies make perforated metal false floors. You can get plans for installing the floors from these companies. Perforated metal floors can also be used in other types of bins.

Hardware cloth can be used instead of perforated metal sheets as material for false floors in drying bins, as shown in figure 13. Place the concrete blocks so that air will circulate through them. Rows of blocks 4½ feet apart, with the blocks laid close together in the row, will support ear corn to a depth of 16 feet or shelled corn or grain to a depth of 9 feet.

If the drying bin is to be used for ear corn only, 1- by 6-inch slats laid flat across the rows of blocks and spaced ¾ inch apart may be substituted for the 2- by 4-inch joists and hardware cloth. Rows of blocks 2 feet apart, with the blocks

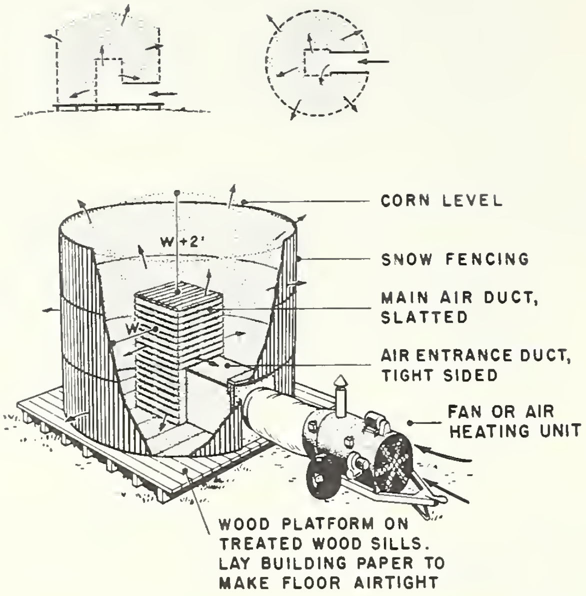

CORN LEVEL
W+2'
SNOW FENCING
MAIN AIR DUCT, SLATTED
W
AIR ENTRANCE DUCT, TIGHT SIDED
FAN OR AIR HEATING UNIT
WOOD PLATFORM ON TREATED WOOD SILLS. LAY BUILDING PAPER TO MAKE FLOOR AIRTIGHT

Figure 9.—**Inexpensive, easily built crib.**

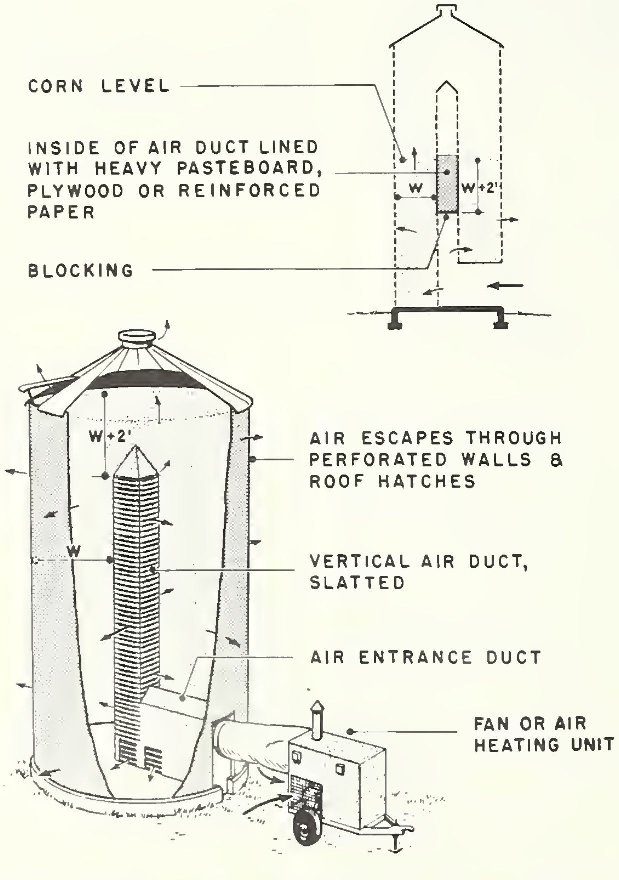

CORN LEVEL
INSIDE OF AIR DUCT LINED WITH HEAVY PASTEBOARD, PLYWOOD OR REINFORCED PAPER
BLOCKING
W
W+2'
W+2'
AIR ESCAPES THROUGH PERFORATED WALLS & ROOF HATCHES
W
VERTICAL AIR DUCT, SLATTED
AIR ENTRANCE DUCT
FAN OR AIR HEATING UNIT

Figure 10.—**High round crib with perforated walls. The main air duct in the center of the crib is vertical and slatted.**

18 inches apart in the row, will support a 16-foot depth of ear corn. Use 2- by 8-inch sills as shown in figure 13.

A duct system that can be used when drying ear corn in rectangular or circular bins is shown in figure 14. For uniform air distribution the ear corn depth should be at least 6 feet. The main duct, shown in figure 14 outside the bin, could be located inside, along one side or at the center of the bin. Build the lateral ducts in about 4- to 6-foot sections so that you can remove them easily while emptying the bin. Details of construction of the duct system are shown in figure 15.

Construction details of a duct system that is suitable for use in several types of bins, as just described, are shown in figure 15. The main duct is usually rectangular in cross section, although it may be rounded or triangular. Allow 1 square foot of cross section area for each 1,000 c.f.m. of airflow from the fan. For example: If the fan delivers air at the rate of 9,000 c.f.m., the cross section area of the main duct should be at least 9 square feet. Such a duct could be 3 feet square.

Space the lateral ducts so that the distance between them, center to center, is not more than half the depth of the ear corn to be dried. If all the lateral ducts are of the same length, you can compute the cross section area required for each by dividing the cross section area of the main duct by the number of laterals. For example: With six laterals of the same length and a cross section area of 9 square feet in the main duct, the area of each lateral is 9 divided by 6, or 1½ square feet. If such lateral ducts are built in rectangular form, two 1- by 10-inch boards, sufficiently braced, for the top and one 1- by 12-inch board for each side would be satisfactory. Laterals may be built triangular or rounded in shape.

The width of each lateral should be at least twice the height of its bottom edge above the floor. This height should be about 7 inches for a lateral spacing of 4 feet, center to center, and 10 inches high for a spacing of 6 feet. In any case, the total area for air passage under all the lateral ducts (height from floor to bottom of lateral times length of both sides and one end of each lateral) should be equal to at least one-fourth of the area of the bin floor.

If you use perforated metal sheets to make the laterals, and the sheets have uniformly spaced perforations equaling at least 10 percent of their total area, you may set laterals directly on the bin floor.

Uniform Airflow

Corn settles from 1 to 3 feet as it dries. Unless allowance is made for settling, the volume of drying air that passes through the corn above the main duct is disproportionately greater than the volume passing through the corn at the sides of the duct. You can allow for settling in cribs or bins with perforated or slatted walls by having the height of the corn above the top of the slatted air duct 2 feet greater than the distance from the duct to the wall. Also, where air enters or leaves the main duct through a sidewall, fill above the top of the air inlet to a height 2 feet greater than the crib width. In cribs or bins with tight walls, settling does not affect uniform airflow if the perforated

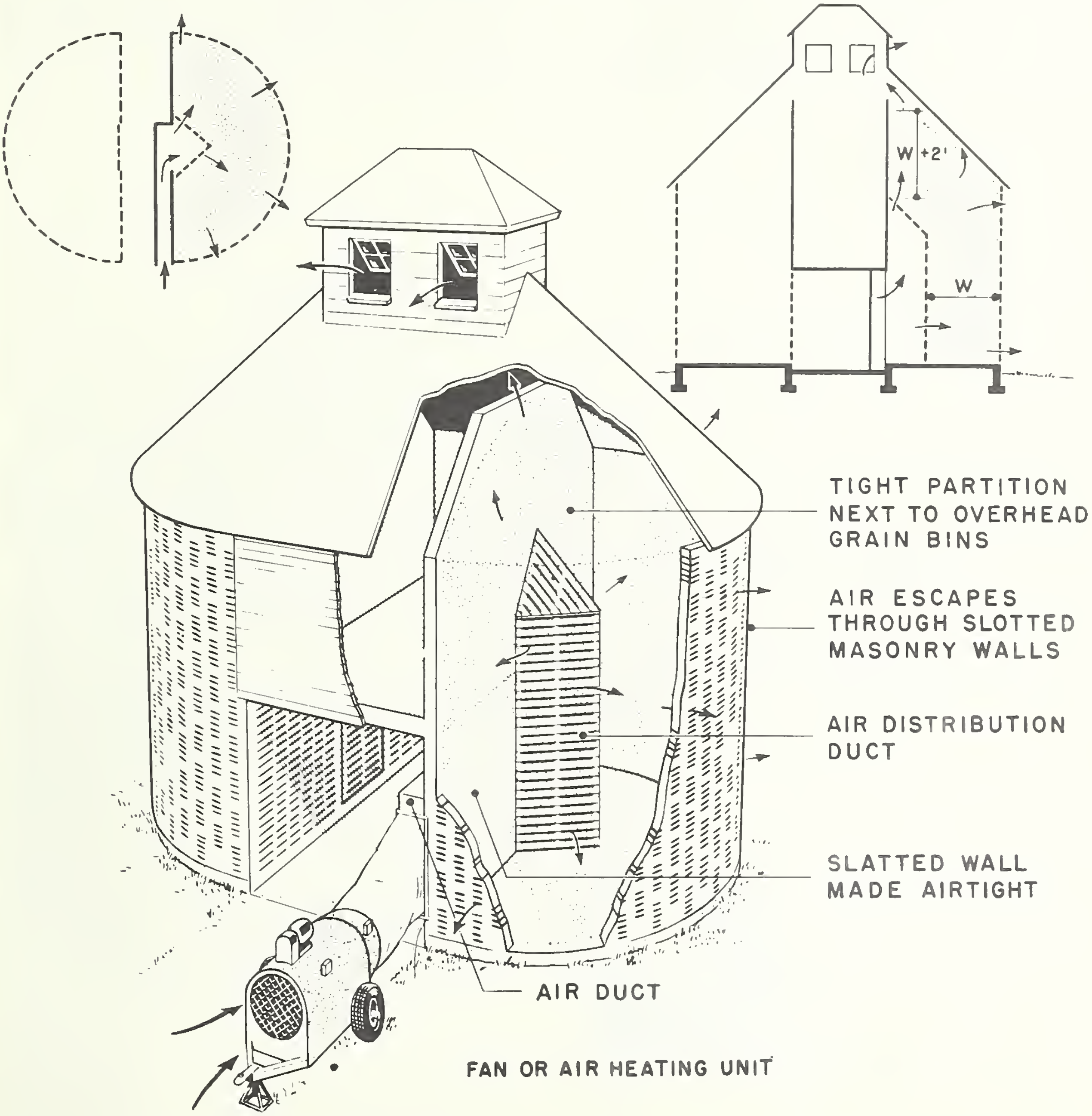

W +2'
W
TIGHT PARTITION NEXT TO OVERHEAD GRAIN BINS
AIR ESCAPES THROUGH SLOTTED MASONRY WALLS
AIR DISTRIBUTION DUCT
SLATTED WALL MADE AIRTIGHT
AIR DUCT
FAN OR AIR HEATING UNIT

Figure 11.—**Suggested arrangement of oval-type masonry crib for the mechanical drying of ear corn.**

floor or ducts are covered with corn to an even depth.

Crossties in cribs prepared as in figures 3, 5, 6, and 7 interfere with even distribution of the air. As the corn dries and settles, a channel forms under each crosstie. These channels permit air to escape from the crib without going through the corn above the crossties. To reduce this loss, cover with paper a strip of the outside wall 2 to 4 feet wide at the level of the crossties. If a shelling trench is not used as a main duct, it should be covered with reinforced paper.

Where air enters the corn through a slatted side or top of the air duct, or through a perforated or slatted floor (all crib and bin illustrations except fig. 14), the slatted or perforated area should equal at least one-third of the floor area.

In some cases, it may be necessary or desirable to ventilate corn in a crib or bin that is only partly filled. With a perforated floor or floor ducts, drying may be started any time after the floor or the ducts are covered to a uniform depth. With the other arrangements shown, some modification of ducts or placement of corn may be necessary when the crib is only partly filled. In planning a drying setup under such conditions, remember that the drying air should travel about the same distance through the corn in all parts of the crib.

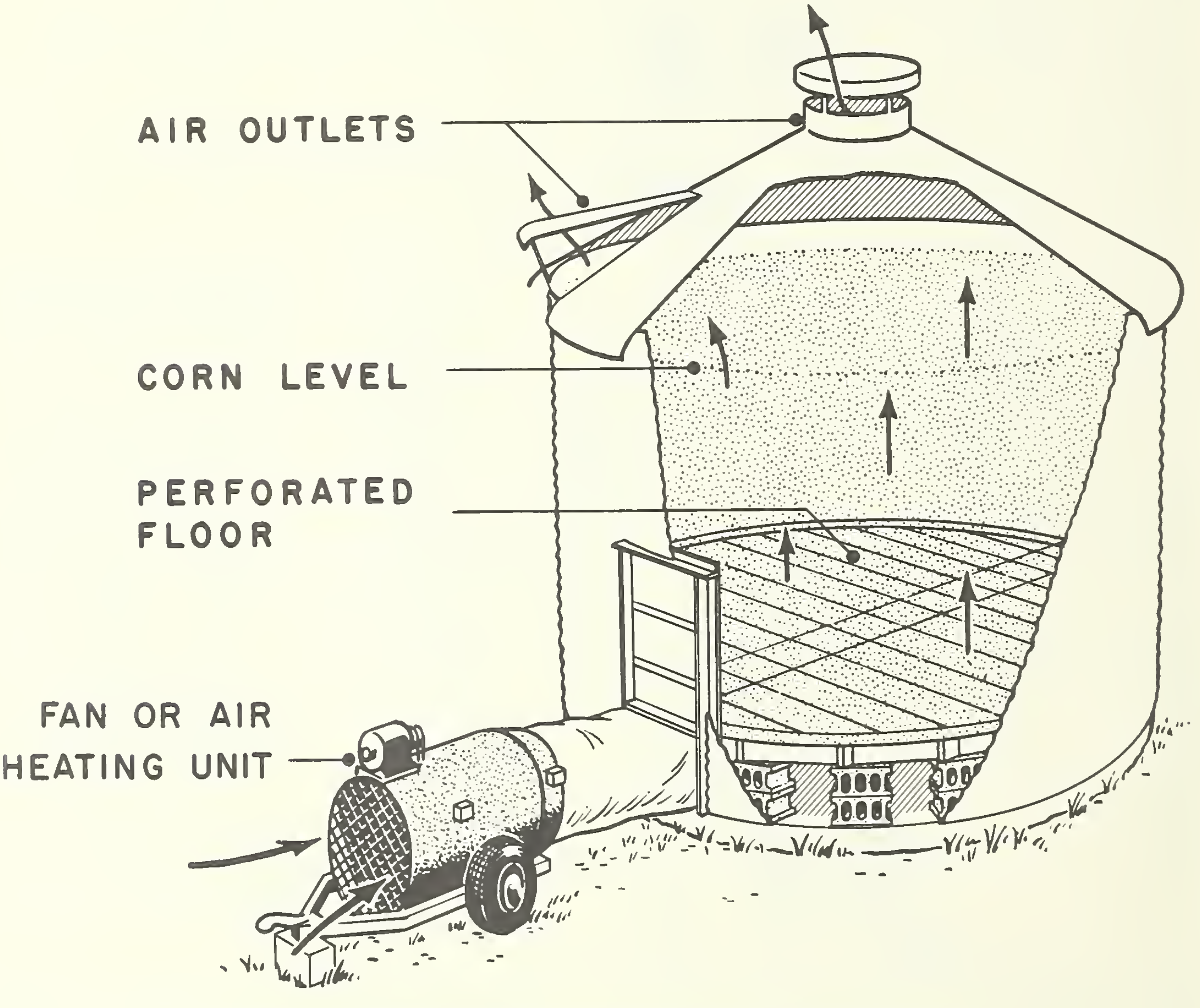


Figure 12.—Circular metal bin with false floor of perforated metal.

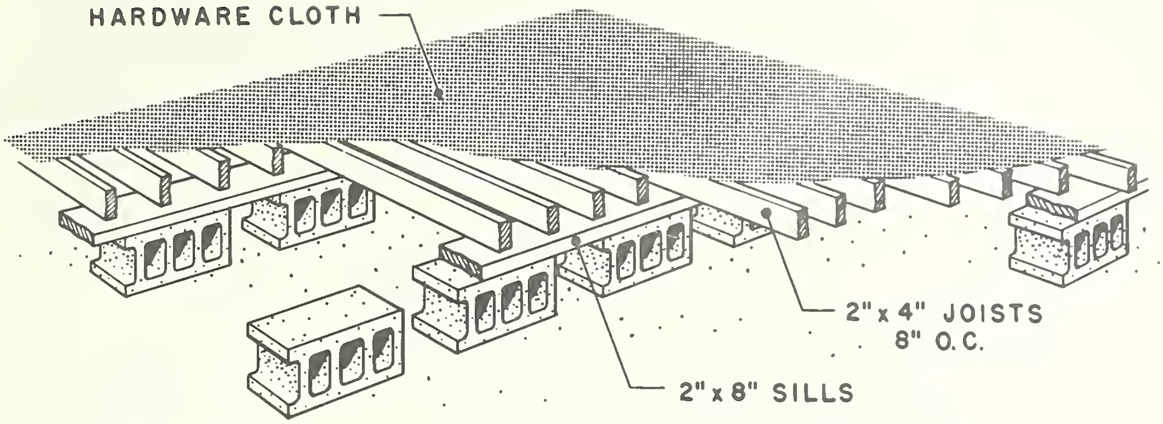


Figure 13.—Details in use of hardware cloth as a false floor in a bin.

Harvesting and Cribbing the Corn

Shelled corn, husks, and silks mixed with the ears tend to fill the spaces between ears and interfere with air distribution. Air will bypass and fail to dry ear corn where these materials accumulate. To prevent this, husk the corn as clean as possible. Also, use a screen in the elevator; this will take out some of the foreign material. Unless the elevator drops the corn on a spreading device in the crib, move the elevator spout frequently, directing it so that any shelled corn will be deposited near the outside wall rather than in the middle of the crib. In cribs such as those shown in figures 6 and 12, which are filled through hatch openings, operating the fan while filling the crib will tend to blow out loose silks and husks.

Operation With Unheated Air

Begin ventilation as soon as there is enough corn in the bin or crib to permit well-distributed airflow. Continuous day-and-night operation is generally best except in case of rain or fog. Corn containing 25 percent or more of moisture is so wet that it will not gain moisture when ventilated with very damp air, unless the corn is colder than the air. High-moisture corn will dry during night ventilation in ordinary weather. A small saving in power cost can be made by intermittent (daytime only) operation. It will take more days—but less actual running time—to get the corn dry than with continuous operation. If you want to ventilate the corn during the daytime only, turn the fan on at about 10 o'clock and keep it running until the corn has cooled in the evening (about 10 o'clock).

Corn at the surface where the air discharges will dry last. When this wettest corn has dried down to 20-percent moisture, you may stop the fan and remove the covering from crib walls if the crib provides good ventilation. In such case the corn will continue to dry naturally to a safe storage moisture content. The moisture content can be measured by testing samples with a grain moisture tester such as used by local elevators.

If you dry ear corn in a bin with tight walls or in a crib with inadequate natural ventilation, run the fan in the fall until the wettest corn is down to around 18-percent moisture or until the corn is frozen. Forced ventilation in winter usually will not pay. If the corn is to be stored through the spring and summer, additional mechanical ventilation will be needed as the weather warms up in the spring.

If mechanical ventilation is to be used to dry ear corn down to 13-percent moisture for shelling and storage, usually the last of this ventilation will have to be done in April and May. At this time, and for this purpose, it is best to ventilate only on warm, dry days, rather than continuously.

If the weather is especially humid after corn is harvested, the corn may not dry enough in the fall for safe crib storage. In this case, run the fan until the corn is frozen. It will not pay to operate the fan further during the winter except to keep the corn frozen. Drying can be completed by additional mechanical ventilation as the weather warms up in the spring. This will add to the cost of drying, but, unless the weather is

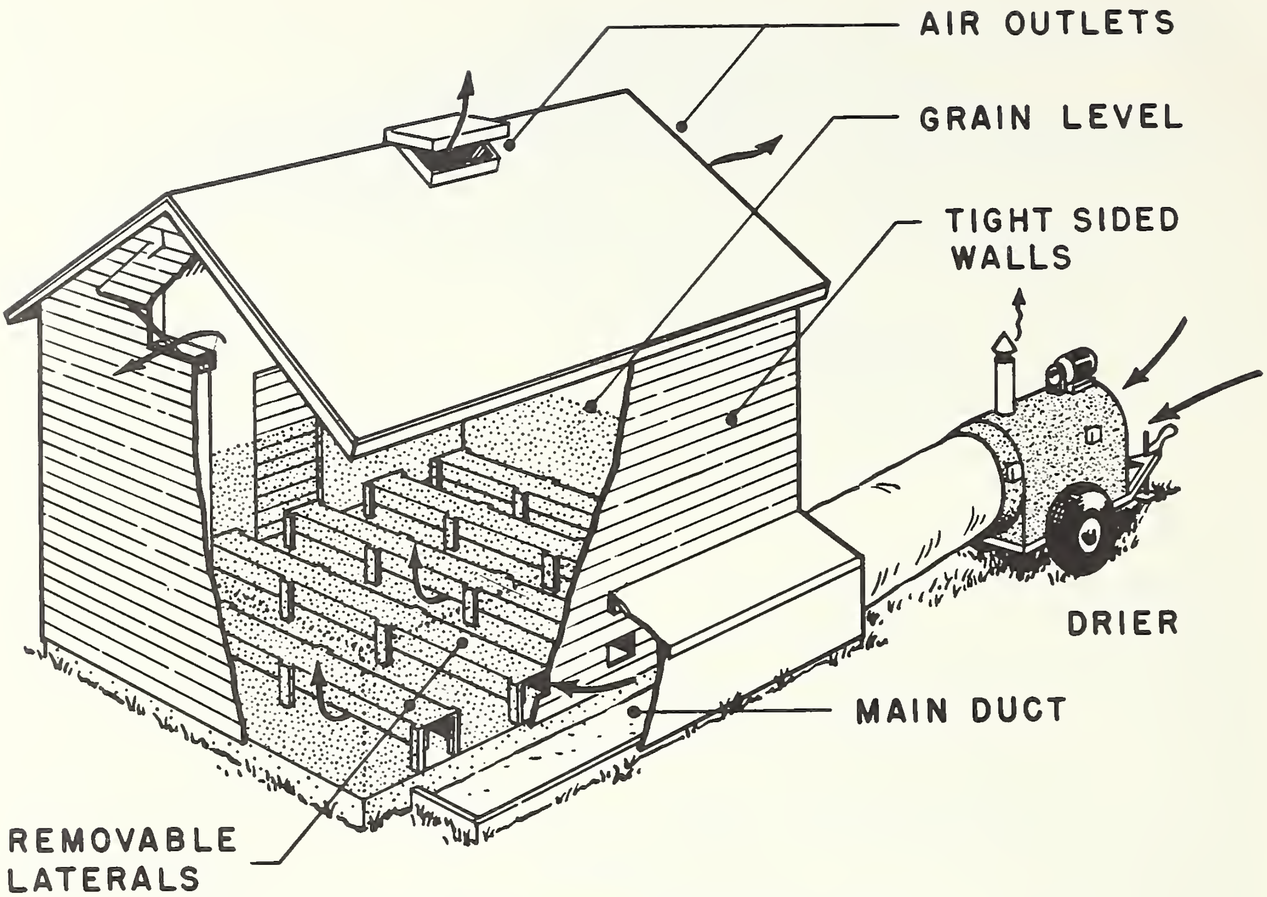


Figure 14.—Rectangular bin with duct system.

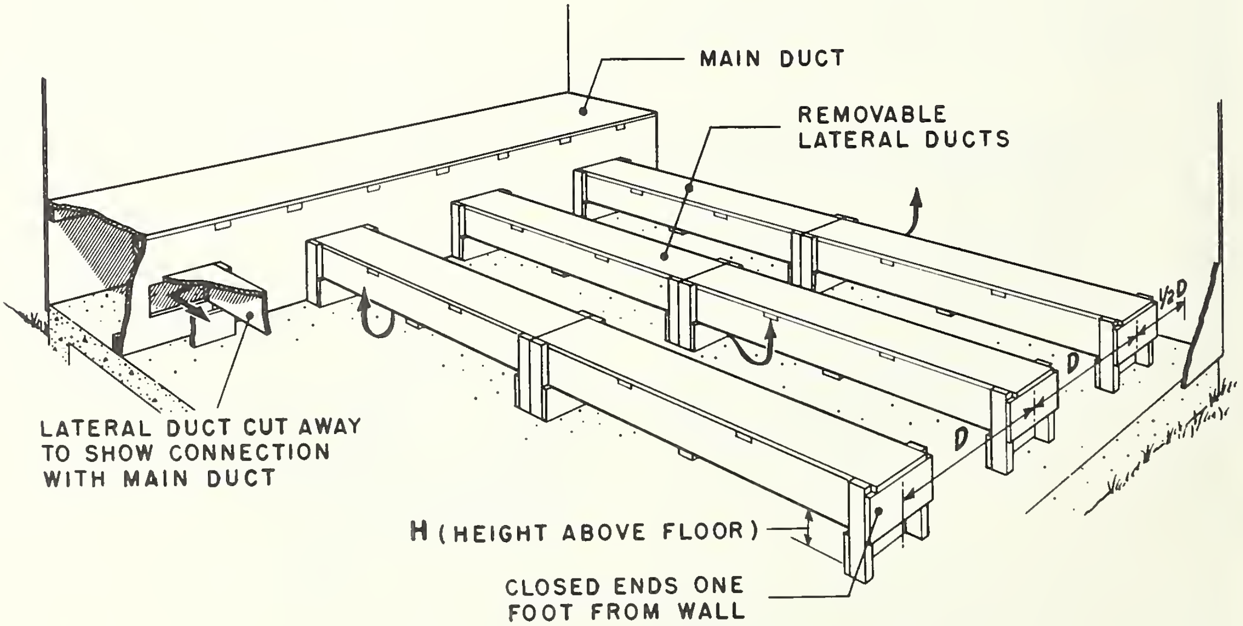

MAIN DUCT
REMOVABLE LATERAL DUCTS
½D
D
D
LATERAL DUCT CUT AWAY TO SHOW CONNECTION WITH MAIN DUCT
H (HEIGHT ABOVE FLOOR)
CLOSED ENDS ONE FOOT FROM WALL

Figure 15.—Details of duct system for drying bin.

unusually humid in early spring, there should not be any serious damage to the corn. It should be recognized, however, that this method of drying does not completely eliminate the weather hazard in curing corn.

Cost.—At an airflow rate of 5 c.f.m. per bushel, a minimum cost for electric power of about 2 cents per bushel is what can be expected for drying corn from a moisture content of 30 percent down to a point where the wettest corn in the crib will be at 20-percent moisture. There also will be overhead cost of equipment—that is, interest, taxes, and depreciation charges—and a small annual cost for covering the crib wall with paper or canvas, if corn is dried in a crib. The total cost for drying ear corn with unheated air may amount to 5 or 6 cents per bushel, assuming 1962 costs.

Operation With Heated Air

When drying with heat, operate the fan continuously.

When drying with supplemental heat, operate the heater either (1) continuously or (2) on and off.

When drying with high-temperature air, operate the heater continuously until most of the corn is dry. With high temperatures, the corn in the bottom layers will get drier than necessary before the top is dry. This unevenness of moisture can be reduced by shutting off the heater and running the fan only. If the corn is to be shelled soon after drying—before the moisture is equalized—the wetter and drier shelled corn should be well mixed before storing. In this situation it is difficult to get adequate mixing, but if it is not done the wetter masses of shelled corn in the storage bin may be a source of trouble. In any case, after the heater is shut off, operate the fan long enough to cool all the corn to air temperature.

Cost.—The cost of drying with heated air is so variable that a simple estimate of cost in cents per bushel for drying ear corn in general would have very little meaning. Initial moisture content, the climate, the relative costs of electricity and fuel, the use to be made of the corn, the heated air temperature, and other factors need to be considered in estimating the cost of drying under your conditions. The section on "Estimating Capacity of Equipment" gives information from which cost estimates can be made.

Estimating Capacity of Equipment

Since the equipment must be selected on the basis of the number of bushels of ear corn to be dried, it is necessary to start with an estimate of quantity of corn. A bushel is defined loosely in a number of different ways. For computation purposes it is convenient to consider a bushel of wet ear corn as the amount that will yield 56 pounds of dry shelled corn. This is the definition used here.

In estimating the capacity of a crib, you may assume that a bushel of ear corn at 15-percent moisture occupies 2½ cubic feet. A bushel of ear corn having a moisture content between 25 and 30 percent occupies 3 cubic feet or more. For estimating the capacity of a crib of wet corn, it is sufficiently accurate to take 3 cubic feet as the space needed per bushel.

Whether heated air or unheated air is used, the minimum rate of airflow shown in table 1 should be used—5 c.f.m. per bushel if 30-percent moisture corn is cribbed or 3 c.f.m. per bushel if no corn over 25-percent moisture will be put in. Table 1 also can be used to estimate the horsepower required.

When using heat, it is somewhat more difficult to estimate the cost of fuel and the total power cost. The decision of how much heat to use, if any, can be made intelligently only by computing the drying time, the fuel cost, and the total power cost for various alternative operations. The information on pages 18 and 19 is for making such computations.

Amount of Water To Be Removed

Table 2 shows the approximate amount of water in a bushel of ear corn at various kernel moisture contents. To find the amount to be removed from each bushel, take the difference between the total pounds at the initial moisture content and the total pounds at the final moisture content. The final moisture when no heat is added usually varies from 12 to 16 percent, the variation depending on the atmospheric humidity. When supplemental heat (the temperature raised by a maximum of 20° F.) is used, the final moisture will likely be 10 to 12 percent. At high temperatures the final average moisture content will be lower unless drying is stopped before the top layers are dry.

Rate of Moisture Removal

Figure 16 can be used to estimate how much moisture will be removed from each bushel in one day. This chart is based on using 5 c.f.m. per bushel. If less air is used, the moisture removal will be proportionately less. For example, at 2½ c.f.m. per bushel, moisture will be removed only half as fast. If an air volume much greater than 5 c.f.m. per bushel is used, the removal will be somewhat less than proportional to the airflow. That is, at 20 c.f.m. per bushel you cannot expect drying to be 4 times as fast as at 5 c.f.m. per bushel. At 5 c.f.m. per bushel or less, the air will be in the corn long enough to come to moisture equilibrium with it.

If the initial moisture is less than about 25 percent, the moisture removal will be less than that shown.

The left-hand scale of figure 16 gives an accurate estimate if the air is saturated before leaving the corn and if no water is added to the air during heating. It is only approximately correct when a direct heater is used, since the products of combustion of the fuel are added to the drying air. At high rates of airflow it grossly overestimates the evaporation. The right-hand scale is an approximation that does not take into account the changing density of the air. For the estimates that usually need to be made, these approximations are as close as is necessary.

The drying time can be computed by using table 2 for estimating the moisture to be removed from each bushel and figure 16 for estimating the moisture removal per day from each bushel.

Cost of Fuel Used for Heating

Table 3 can be used to estimate the amount of fuel required per day when using 5 c.f.m. per bushel. This too is an approximation but a satisfactory one for practical purposes. If other than 5 c.f.m. per bushel is used, the fuel consumption will be proportional to the rate of airflow. For example, raising the temperature 10 degrees will take four times as much fuel when using 20 c.f.m. per bushel as when using 5 c.f.m. per bushel. When using 2½ c.f.m. per bushel, raising the temperature 10 degrees will take only one-half as much fuel.

The following example is a specific case computed from the information on pages 18 and 19.

Table 2.—*Approximate amount of water in ear corn when harvested, at different percentages of moisture content of the kernels*

Kernel moisture content (percent)	Amount of water in a bushel of ear corn [1]		
	In kernels	In cobs	Total
	Pounds	*Pounds*	*Pounds*
35	25. 4	12. 4	37. 8
30	20. 2	9. 9	30. 1
28	18. 4	8. 8	27. 2
26	16. 6	7. 8	24. 4
24	14. 9	6. 7	21. 6
22	13. 3	5. 5	18. 8
20	11. 8	4. 4	16. 2
18	10. 4	3. 2	13. 6
16	9. 0	2. 1	11. 1
14	7. 7	1. 4	9. 1
12	6. 5	0. 9	7. 4
10	5. 3	0. 5	5. 8

[1] A bushel of ear corn is defined here as the quantity that will yield 56 pounds of shelled corn at 15.5-percent moisture.

Table 3.—*Approximate daily fuel requirement per bushel of ear corn for each °F. of temperature rise when using 5 c.f.m. of air per bushel*

[This is for a direct-fired heater. With an indirect heater tbe fuel requirement will be greater by about 40 percent]

Fuel	*Fuel requirement (gallons)*
Fuel oil	.0010
LP gas	.0014

Ear corn at 30-percent kernel moisture will be dried by using 5 c.f.m. per bushel. The average atmospheric conditions are expected to be 48° F. and 63-percent relative humidity. This is the average temperature and humidity in an average season during October for central Iowa.

(1) If the corn is dried at atmospheric temperature, the final moisture will be about 14 percent. Table 2 shows that 21.0 pounds of water must be removed. Figure 16 shows that about 0.7 pound will be removed each day. At this rate drying will take about 30 days of drier operation. The same time will be required for any amount of corn if the air rate is 5 c.f.m. per bushel.

(2) If 10 degrees of supplemental heat is used, the final moisture content will be about 12 percent. About 22.7 pounds of water must be removed (table 2). About 1.25 pounds of water will be removed each day and drying will take 18 days (fig. 16). If LP gas is used, the amount required per bushel each day will be 10×0.0014 gallon, or

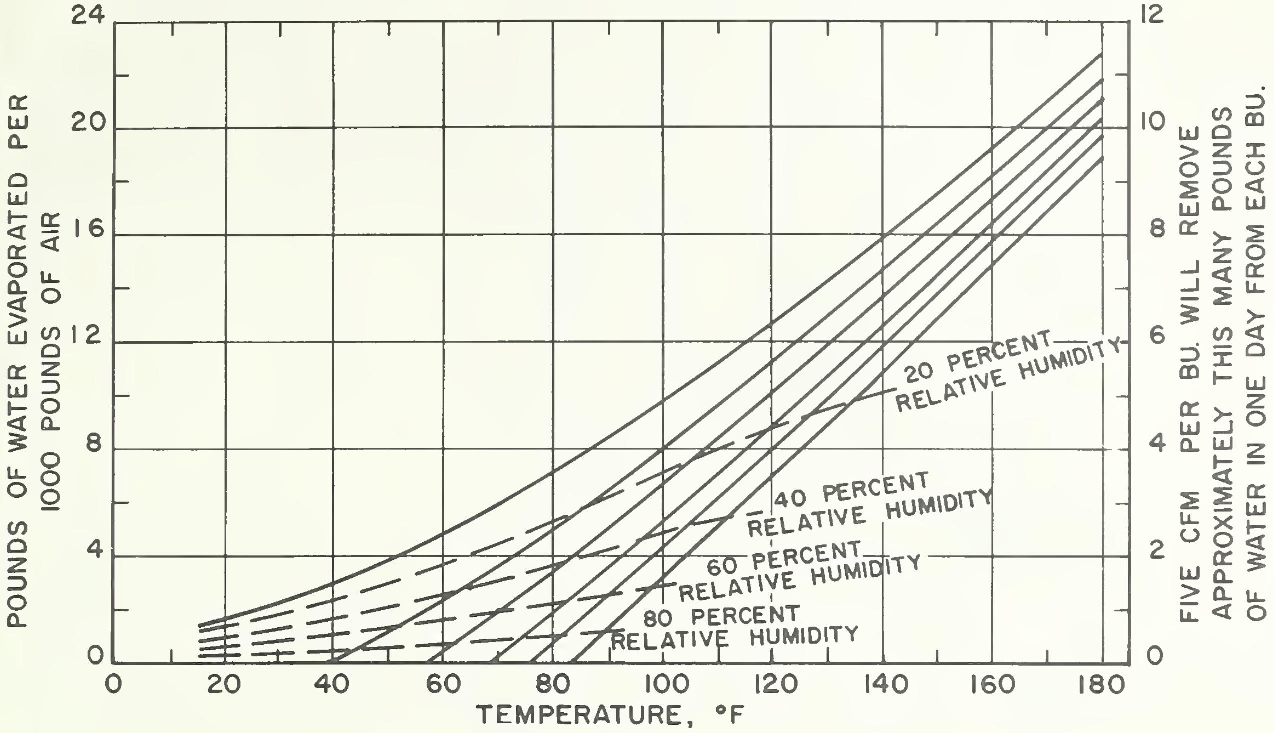


***Figure 16.*—Capacity of air at various conditions for picking up moisture.**

To find the amount of water picked up by 1,000 pounds of air:

A. With unheated air.
  1. Find the intersection of the vertical line representing the atmospheric temperature with the dashed line representing the relative humidity.
  2. Move horizontally to left margin and read pounds of water.

B. With heated air.
  1. Find the intersection of the vetrical line representing the atmospheric temperature with the dashed line representing the relative humidity.
  2. Move to the upper right along the solid sloping line to the vertical line representing the heated air temperature.
  3. Move horizontally to the left margin and read pounds of water.

In either case, to find the approximate amount of water removed from each bushel in 1 day when using 5 c.f.m. per bushel, move to the right margin instead of to the left.

0.014 gallon (table 3). Since drying will take 18 days, the fuel required per bushel will total 18× 0.014 gallon, or 0.25 gallon.

(3) If the air is heated to 140° F., the final moisture content will be 10 percent. (The operator may stop when the average moisture is down to a suitable level and finish by ventilation with unheated air or he may choose to continue drying until the top layer is down to 13 or 14 percent, in which case the average for the crib will be lower than 10 percent.) Table 2 shows that 24.3 pounds of water must be removed. About 7.5 pounds will be removed each day and drying will take 3.5 days (fig. 16). If LP gas is used, find the amount required per bushel by consulting table 3 and making the following computation:

$140-48=92.$
$92\times 0.0014=0.13$ gallon of gas per bushel in 1 day.
$3.5\times 0.13=0.45$ gallon per bushel.

The example brings out the fact that as more fuel is burned, the operating time is less, and therefore the power cost is decreased. With given prices of fuel and electricity, it is easy to compare the total cost of fuel plus power.

Information on drying shelled corn and forage crops by mechanical ventilation is available from your county agricultural agent, from the Extension Service agricultural engineer at the land-grant college or university in your State, or from the U.S. Department of Agriculture, Washington 25, D.C.

This publication supersedes Leaflet 333, "Drying Ear Corn With Heated Air," and Leaflet 334, "Drying Ear Corn With Unheated Air."

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